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Department of Agriculture Federated Malay States

Bulletin No. 13.

A ROOT DISEASE OF THE PARA RUBBER TREE.

(FOMES SEMITOSTUS, BERK.)

BY

KEITH BANCROFT, M.A., (Cantab), F.L.S.

Mycologist, F.M.S.

Kuala Lumpur, Federated Malay States
April, 1912.

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PREFACE.

Bulletin No. 2, entitled "Root Diseases of *Hevea Brasiliensis*, the Para Rubber Tree," by W. J. Gallagher, Government Mycologist, was issued by the Department of Agriculture, F. M. S., in 1910. It was devoted to an account of the root disease caused by *Fomes semitostus*, along with a note on what has since been identified as "the brown root disease" (*Hymenochaete noxia*). Since 1910, the study of the root diseases of the Para Rubber Tree has been continued, and several factors in connexion with the spread of the mycelium of *Fomes semitostus*, its action on the plant, its hosts, its relation to *Termes Gestroi* etc., have been brought to light; while time has allowed of careful observations being made on the effect of different methods of treatment. It is accordingly considered advisable to issue a further account of the common root disease of the Para Rubber Tree which is contained in the present Bulletin No. 13.

L. LEWTON-BRAIN,
Director of Agriculture, F. M. S.

A Root Disease of the Para Rubber Tree.

(*Fomes semitostus*, Berk.)

By Keith Bancroft, m.a. (Cantab.), f.l.s.

HISTORY AND DISTRIBUTION.

Fomes semitostus, to which is attributed the common root disease of the Para rubber in the Federated Malay States, was first observed by Hooker in M. Khasia and was described by Berkeley in Hooker's journal in 1854. Berkeley's description included only the "bracket" or dimidiate form of fructification. Subsequently another, the resupinate form, was recorded by Beccari in Sarawak.

In the original description there is no mention of the fungus being a parasite, the fructification being merely said to have been found on dead wood. In 1904 Ridley reported the fungus as a parasite on the Para rubber; he stated that some time previously two trees had been badly burnt by a bonfire and had died, when the neighbouring two or three trees on either side were found to have been destroyed and the fructification of a fungus appeared on the trunk. The fructification was identified by Massee at Kew as that of *Fomes semitostus*. The trees which were referred to by Ridley had evidently been damaged by the fire and the fungus would accordingly appear to have been a "wound parasite." This is of some interest because subsequent investigations have shown that the fungus is capable of attacking uninjured plants.

Since Ridley's discovery of the parasitic nature of the fungus, the root disease has been found to be present in considerable quantity in the Federated Malay States. In Ceylon the disease was first recorded in 1905; but it appears to be common only in one district. In addition, the disease has been reported from Southern India; while in Java a similar disease is known, but the fungus has not yet been identified. Petch says that specimens of mycelium which were received from the Gold Coast were similar to those of *Fomes semitostus*. And I have recently learnt that the fungus is known as a parasite in the Belgian Congo.

In so far, then, as its geographical distribution is concerned, the fungus is somewhat widely distributed in the East and is said to occur in tropical Africa. There is hitherto no mention of its occurring in the Western Tropics.

Both the fructifications and the mycelium of the fungus have been found to occur in the jungle in this country. After the jungle is felled and burnt the fungus appears in the "clearings." From its occurrence in recent "clearings" on the stumps and logs of dead jungle trees it is concluded that the mycelium, which is thus present, is derived from the mycelium which existed in the jungle before it was felled; in other words, the mycelium is supposed to survive the burning of the jungle. As will be shown later on, the cases of the root disease which occur among young rubber trees are considered to be mainly due to infection derived directly from the stumps of jungle trees; and from observations which have been conducted on a large number of planted areas it would appear that a period of about four years is in the majority of cases sufficient for the living trees to derive infection from the stumps which were infected in the jungle. In order then to obtain a knowledge of the original distribution of the fungus in the jungle, it would be necessary to consider only those areas which are opened up from virgin jungle and in them to record the number of cases of the root disease during the first, say four or five years of cultivation. This gives approximately the relative quantity of the fungus in different areas before they were opened under cultivation. In areas which have been under cultivation for a longer period the number of cases of the root disease which is recorded in later years depends on the employment or absence of employment of methods of treatment and cannot, therefore, indicate the quantity of the fungus which was present before they were cultivated.

There are, roughly speaking, two types of soil occurring in Selangor, Perak and Negri Sembilan, *viz.*, the alluvial clayey soils which are adjacent to the rivers and to the sea, and the light loamy soils or sandy loams which are situated further inland and on higher ground. The effects of the fungus have been more severely felt on the lowlying alluvial soils. This, however, does not appear to be due to the fungus being generally distributed in greater quantity on the lowlying land, but rather to the fact that its spread in the planted area is more active under damp conditions.

On the lowlying land as well as on higher land the fungus is comparatively scarce in some areas, while in

others it is more or less abundant. It is by no means unusual to find on one estate a death-rate of 12% of trees during the first few years of cultivation, while its immediate neighbour, possessing similar soil and opened up from similar jungle, will yield only 2% of cases of the disease during the same period. On the lowlying land, on which the effects of the disease have been generally more severe, there are areas, consisting of two or three thousand acres, in which the average percentage of cases of the disease is 2% or 3% during the first few years of cultivation; and on the higher land a death-rate of as many as 16% of trees has been recorded in the first three or four years of cultivation. It is, therefore, plain that no hard and fast lines can be drawn between areas of comparative scarcity and abundance; and it is in no way possible to predict whether a certain area which is being opened under cultivation will yield a small or a large number of cases of the root disease.

It has been supposed that the quantity of the fungus which is present in any area depends on the number of its hosts in the virgin jungle. This assumes that the fungus possesses a limited or definite number of hosts in the jungle; but, as will be shown later, there is no reason to suppose that the plants on which the fungus occurs in the jungle is limited to any small number. It would appear to be more reasonable to regard the occurrence of areas of comparative scarcity and abundance as obeying the general laws of distribution of organisms of such a kind.

THE SYMPTOMS OF THE DISEASE.

On plantations the infected areas are usually scattered. Groups of trees, here and there, are usually attacked. Sometimes a single tree is infected; but usually two or more, up to eight or nine adjacent trees are attacked at each centre or area of infection. Cases of the disease usually commence to occur in the planted area at the end of the first year or first eighteen months after planting, although they may sometimes be recorded earlier. The number of cases continues to increase until the end of the third or fourth year when it commences to diminish, providing that the cases are treated as soon as they make their appearance.

Typically, the symptoms observed above ground, when a tree is attacked, are those which generally occur in root diseases; they are the resultant effect of the stoppage of the supply of water (and mineral food) from the roots to the

leaves. The leaves wither, turn yellow or brown and die. The softer tips of the shoots also wither. This initial withering usually escapes notice, but careful observations have shown that the death of the parts above ground is usually complete in three or four days after the wilting commences.

No latex flows when an incision is made in the trunk—another symptom of the lack of available water.

The initial wilting of the young shoots and the rapid death of the parts above ground are the symptoms which are most commonly met with. Sometimes, however, an attacked tree may look unhealthy for several weeks before it dies. This is apparently due to the diminution of the supply of water and mineral food by the gradual destruction of the roots. In some cases the tree is able to live for an appreciable time after all of the roots, except a single lateral and a part of the tap root, have been destroyed.

The symptoms which are visible above ground usually allow of no time for treatment of the disease; and, in addition, owing to the destruction of the tap root the tree may be blown over or may fall by its own weight before any symptoms become visible. Petch records an instance in which 700 trees on one estate in Ceylon were blown over in a single night owing to the destruction of their tap roots by the fungus. Although there has not been, to my knowledge, so heavy a loss recorded in the Federated Malay States at any one period as the result of the action of the fungus, yet considerable losses have occurred from time to time among trees growing on peaty land where the tap roots are necessarily short. The tap root of the plant is its main agent of support and its absence or destruction necessarily renders the plant unstable.

If the roots of an attacked tree be examined they will be found to bear the mycelium of the fungus superficially. Sometimes the mycelium may give rise to a felted growth; but it always exists in part in the form of strands which spread on the surface of the roots. The younger strands are white and branch repeatedly, the ultimate branches passing into thin fibrils which become almost lost to the naked eye. Where the branching is profuse the strands may sometimes possess a fan-like appearance. The photograph facing page (8) shows the younger strands of mycelium. The older strands take the form of cords which may be either white or brownish yellow in colour; in some cases they may possess a reddish tinge mixed with the yellow

Photograph 1.

colour. The photograph facing page (10) shows the older strands of mycelium. The strands vary from thin fibrils to stout cords, measuring as much as ¼ inch in diameter. When they are in contact with the surface of a root they are frequently closely adpressed to it and can only be removed with difficulty. Both the younger and the older strands may produce a network on the surface of the root.

When a tree dies, an examination of its roots will frequently show that one or two laterals are only recently dead, while the other laterals and parts of the tap root have been dead for some time and may have even reached a period of decay. This will to some extent depend on the rate of growth of the fungus; but the root or roots which were first attacked can usually be distinguished and will indicate the direction from which the infection started. An attempt should always be made to trace the point of origin of the infection by observation on the roots, since this will frequently enable the cultivator to locate the source of infection. Sometimes the tap root is first affected, but the infection usually commences on one of the laterals.

The instability resulting from the destruction of the tap root has been referred to above. The tap root is sometimes rapidly destroyed by *Termes Gestroi* following on the attack by the fungus. Both *Termes Gestroi* and the fungus are frequently associated with each other on the roots of *Hevea;* the insect is far more rapid in its action than the fungus and for this reason the destruction of trees is often attributed to the insect when there is good reason to believe that they were first attacked by the fungus. In the majority of cases in which both the root fungus and "white ants" are found attacking trees of *Hevea* the initial attack is due to the fungus; and it would appear to be likely that trees which are affected by the root disease are more susceptible to attacks from "white ants." Trees which are primarily attacked by the fungus and subsequently by "white ants" may in the later stages of disease show no signs of fungus attack owing to the disappearance of the strands of mycelium. Such cases are invariably diagnosed as being due to "white ants" only; and, on the whole, it would appear that a large proportion of the damage which is attributed to "white ants," more particularly among older trees, is initiated by the root fungus. In young "clearings," on the other hand, many trees are attacked by "white ants" without any intervention on the part of the fungus.

From the superficial strands the mycelium penetrates the bark and thence passes into the wood. The growth of the mycelium in the bark would appear to be somewhat in advance of the growth in the wood. When killed, the bark possesses the usually brown colour of dead bark. The action of the mycelium reduces the wood to a dry, friable mass.

SPREAD.

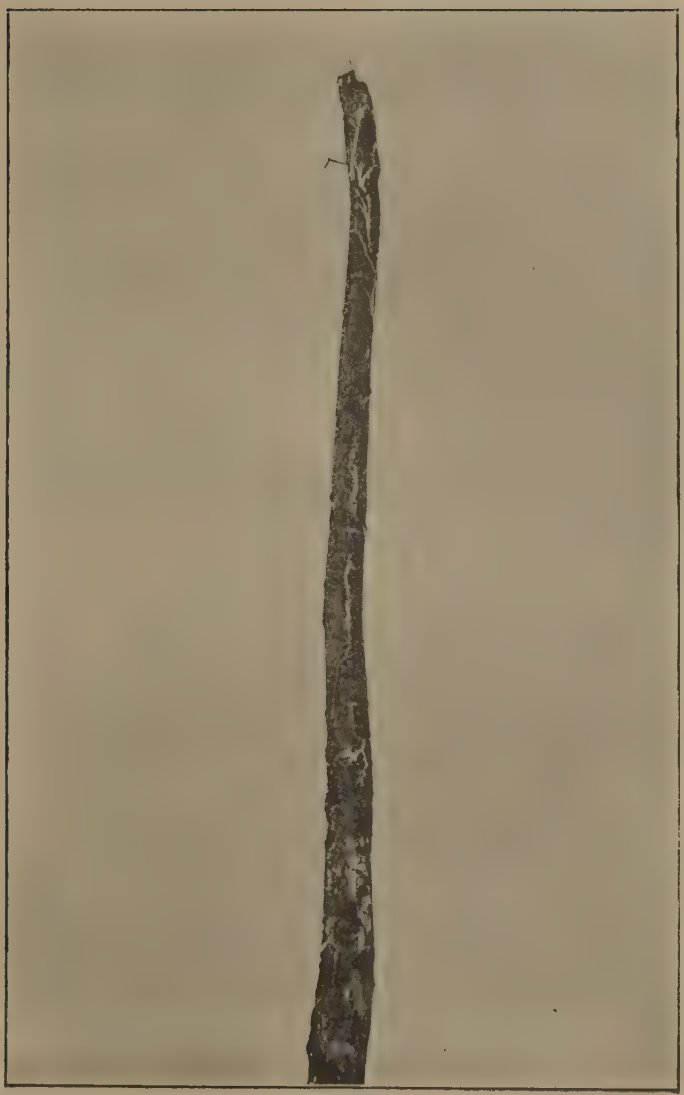
For practical purposes it will be necessary to consider the spread of the disease from two sources; the one is the spread by the growth of the mycelium and the other is the spread by means of spores. The former constitutes the more important means of propagation and will, therefore, be dealt with first.

A. SPREAD BY MYCELIUM.

Growth in the soil. By placing pieces of infected roots in damp soil the mycelium can be induced to grow out from the superficial strands and also from the cut surfaces of the roots. Roots which have recently died have been found to give the best results, since on these the growth of the mycelium is most active. If the soil be kept damp the mycelium will frequently spread through it, permeating it with silky white strands. On heavy soils I have so recorded a spread for a distance of nearly a foot from the infected root under very damp conditions.

When the mycelium has been thus allowed to grow through the soil, if the infected root be removed, the hyphae soon die, there being no evidence of any mycelium in the soil at the end of four or five days after the root has been removed. Similarly, if the mycelium does not come into contact with any material from which it can derive nutriment it soon dies out. The growing mycelium does not appear to have any appreciable capacity for retaining its vitality when it is separated from its source of nutriment.

It has also been demonstrated that if young plants of *Hevea* be planted in soil containing the mycelium of the fungus, but from which all infected roots have been removed, the plants do not become attacked by the mycelium. I have made many attempts to infect young plants of *Hevea* by growing them in soil in which a growth of the mycelium has been produced from an infected root, but I have never obtained any positive results. In each experiment the



Photograph 2.

infected root was placed in damp soil in a box, and when the mycelium had grown through the soil for an appreciable distance, usually 4 or 5 inches, the root was removed leaving the mycelium in the soil. Two young plants of *Hevea*, three or four months old, were then planted in the soil, and the soil was kept damp. The roots of the plants were examined at the end of two months, and it was found that the strands of mycelium had disappeared and that the roots were apparently healthy.

Observations in the field have shown that if the stump and roots of a dead tree be removed from the ground the mycelium of the fungus soon disappears from the soil. These observations, therefore, confirm the results which attended the above experiments. The capacity of the mycelium for resting in the soil has an important bearing on the "supplying" of the infected areas, since, if the mycelium were capable of resting in the soil it would be necessary that a sufficient period of time should be allowed for the mycelium to die before the area was supplied.

The mycelium which is in contact with and in the tissues of dead roots appears to be capable of enduring a period of comparative inactivity. During periods of drought in this country the growth of the mycelium is checked and with the recurrence of the rainy weather it recommences; this is shown by the recurrence of fresh cases of disease after the commencement of the wet weather. It is important, therefore, that careful attention should be paid to the removal of all dead roots from an infected area before a "supply" is put in, since each infected root is capable of giving rise to a fresh growth of the mycelium.

The fungus is one of the agents which are responsible for the decay of timber. It has been found, by leaving attacked trees in the ground and making observations on the growth of the mycelium, that the mycelium grows most actively when the material is dying and when it is recently dead. As decay commences to set in the growth diminishes and finally ceases altogether; the mycelium which is deprived of fresh material then disappears. There is a rapid growth of mycelium in recent "clearings" where there is an abundance of dying and of recently dead material. Old stumps, on the other hand, which have reached a period of decay seldom harbour the mycelium; and where the mycelium does occur on such stumps its growth is not rapid. The time at which the danger of infection is greatest would accordingly appear to be soon

after the felling and burning of the jungle. Land which has been felled and allowed to become covered with lalang for several years, as is met with in many parts of the Federated Malay States, seldom yields a single case of the root disease when it is cultivated in *Hevea*. To sum up the results of these observations, it may be said that the large number of cases of the root disease which occur among *Hevea*, when it is cultivated on land derived from virgin jungle, is due to the Hevea having been planted before the timber was allowed to decay.

The decay of timber has, therefore, an important bearing on the root disease. The time-rate of decay of various timbers varies according to their nature and to the agents which are at work. The hardest woods tend to last longest and the decay produced by insects is more rapid than that caused by microorganisms. The average time-rate of decay of different timbers in this country is not accurately known. Stumps can still be seen on land which was felled and burnt five, six or seven years previously; while some stumps are evident after longer periods of time.

The relation of the growth to moisture, etc. It has been shown that the growth of the mycelium may be obtained if a piece of an infected root be placed in the soil. The growth is more active if the soil is kept damp than it is under drier conditions. Clayey soils, which have a high retentive power for water, produce a more active growth of mycelium than do soils of looser texture. In the field it has been found that a very rapid growth usually occurs in the lowlying alluvial soils in this country. Where the water level in these soils is at a comparatively short distance from the surface the growth of the mycelium is particularly rapid. In some of these areas it has been possible to observe the white strands of the fungus passing through the soil by merely removing the surface of the soil to the depth of a few inches. In land which is situated at higher levels and where the soil is looser in texture the mycelium does not exhibit any appreciable passage through the soil. For this reason a single jungle stump will frequently infect a larger number of adjacent trees on damp, lowlying land than on lighter, higher land; and it is owing to the more rapid growth of the mycelium under damp conditions that the losses occurring on the lowlying alluvial land have, generally speaking, been the heavier.

Gallagher considered that the fungus was unable to travel for any distance through the soil unless it was in

contact with roots. Petch states that when the mycelium has permeated a stump it spreads through the soil in search of other food, either along pieces of wood or independently, and that the fungus can advance through the soil unattached to any tissues, either living or dead. I have only been able to observe an independent passage of mycelium through the soil where the fungus is growing under damp conditions.

The independent passage of the mycelium through the soil appears to depend on two factors; the one is its rate of growth and the other its capacity for deriving nutriment through the strands from some distant source. While some fungi which are known to be parasitic on the roots of plants possess to a marked degree the power of spreading through the soil independently of contact with plant material, *Fomes semitostus* appears to spread through the soil to an appreciable extent only when its growth is particularly rapid. Like several other "root fungi" *Fomes semitostus* grows most actively under damp conditions, and it is concluded that by virtue of its more rapid growth under these conditions the independent passage of the mycelium through the soil becomes evident.

From the above considerations it is clear that the rate of growth of the mycelium is closely related to the water-content of the soil. Drainage is, therefore, an important consideration in the treatment of the disease.

Light appears to inhibit the growth of the mycelium. The mycelium does not grow on the surface of the soil or on the exposed parts of plants. When it occurs on logs lying on the ground it is always confined to the under surface.

It has been found that the mycelium grows rapidly in peaty soils where there is an abundance of vegetable matter and a high water-content, along with the presence of humous acids. Acidity of the soil is, generally speaking, favourable to the growth of the mycelium of fungi.

Depth of occurrence. The lateral roots of the trees of *Hevea* usually ramify in the uppermost eighteen inches of the soil, and for this reason the mycelium of the fungus is usually found to be more abundant in the upper layers. It can, however, occur at greater depths. I have recorded it on the tap roots of plants to a depth of as much as two and a half feet from the surface, and it can be frequently found on tap roots at greater depths than eighteen inches. Petch states that the depth of the tap root which is covered by the mycelium may be as much as thirty inches. Sometimes on the sides of drains the fructifications can be seen at depths

of three or three and a half feet below the surface of the ground. These fructifications take origin from the cut surfaces of roots which abut on the sides of the drains and which bear the mycelium of the fungus. It is, therefore, important to bear in mind that the fact that the mycelium is usually situated in the upper eighteen inches of the soil is only due to its occurrence on the lateral roots in the upper layers; where the lateral roots penetrate to greater depths the mycelium may occur at greater depths also. The depth to which the mycelium can occur is obviously of primary importance in connexion with the treatment of the disease by the isolation of infected areas; and from the above observations it is necessary that the trenches which are made for isolating diseased areas should be carried to a depth sufficient to sever the lateral roots of the adjacent trees.

The infection of living roots. Most usually the disease makes its appearance in the planted area in about twelve or eighteen months after planting has been done. As will be shown later, this is not due to any inability on the part of the fungus to infect very young plants. It appears to be due to the time required for the lateral roots to grow sufficiently in order to come into contact with the mycelium of the fungus, and also to the time required for the trees to succumb to the disease after they have been attacked. Cases occur in which young plants develop symptoms of the disease at the end of four or five months after they have been planted in the field; sometimes this is due to the plants having been infected in the nursery before they were lifted for planting, and at other times it appears to be due to planting in actual contact with the roots of infected jungle trees.

Experiments have been conducted for the purpose of ascertaining whether it were possible to reproduce the disease artificially. Seedlings, three months old, were transplanted from the nursery into boxes at a distance of one foot apart, care being taken to remove a quantity of soil with each seedling in order to avoid damaging the roots. A piece of an infected root of the Para rubber, bearing strands of mycelium, was placed in contact with the roots of each seedling. In the experiment tabulated below six seedlings were employed, and of these four were infected, the remaining two acting as controls. The soil was supplied every day with sufficient water to keep it moist. The results of the experiments are tabulated thus:—

Number of Seedling.	Date of infection.	Date of death.	Remarks.
I	November 10th	January 10th	Death followed rapidly after wilting
II	do.	December 17th	Symptoms as in I.
III	do.	January 14th	do. as in II.
IV	do.		No Symptoms of disease.
V	Not infected.		do.
VI	Not infected.		do.

It will be observed in the above experiment that three of the infections were successful out of the four. The failure of the fourth appeared to be due to the absence of development of strands of mycelium from the dead root. The controls showed no symptoms of disease. Two other experiments, which were conducted on similar lines, yielded similar results. Altogether ten out of fourteen plants were successfully infected. The experiments show that it is possible to infect artificially living plants from dead roots which bear the mycelium of the fungus; and from observation this is concluded to be the usual method of infection in the field.

It is important to ascertain whether the age of the plant bears any relation to its susceptibility to the root disease, *i.e.*, whether the plant is more susceptible at one period of its existence than at another period. It has been mentioned above that cases of the root disease commence to occur in the planted area usually at the end of the first year or first eighteen months after planting. There are, however, some instances in which cases of the root disease have been recorded earlier in the planted area. The experiments described above show that plants three months old may be artificially infected, and in the nursery it has been found that seedlings may become infected from logs and roots which are buried underground. Nursery infections are not however common, because the beds are usually cleared of timber before the seed is sown. But there have been some instances in which infected plants have been transplanted from the nursery. In one instance I was able to record a loss of fifteen adjacent trees from this source in the planted area; and in another case a large number of six-months-

old plants were received at the laboratory, which had died from the root disease, although there was no sign of the mycelium of the fungus on any of the adjacent jungle stumps. In the latter case the plants had only been recently planted and there appeared to be no doubt that they had been infected in the nursery before they were "lifted." Unfortunately, it was not possible to make an examination of the nursery beds. In addition, there have been several cases recorded from time to time in which nursery infection has been suspected. The fact that the plant may develop the root disease when in "seedling stage" may accordingly be considered to be satisfactorily established. Observations on older plants have shown that trees of all ages varying from one to thirteen years have succumbed to the disease.

It is necessarily difficult to make accurate observations on the time taken for plants to die after they have become infected. Apart from any individual resistance to the disease there are three primary factors which appear to influence the time-rate of death of the plant from the root disease, *viz.*, the age of the plant, the point of origin of the infection and the condition of dampness of the soil. In connexion with the first of these factors it is clear that the older the plant is the greater will be its root system; old plants may accordingly be expected to hold out for a longer period against the destructive action of the fungus. Secondly, infection on the tap root may be expected to produce a more rapid effect than infection on one of the lateral roots. And thirdly, the rate of growth of the mycelium has been shown to be influenced by the water-content of the soil. Areas from which the timber has been removed may continue to yield cases of the disease for a further period of as much as three years, even providing that these cases are treated as soon as they appear. From this it may at first appear to be reasonable to conclude that the maximum time taken for a plant to die after it has become infected would be somewhere in the region of three years. But, observations on such areas are not always satisfactory, because there is usually a certain amount of timber left underground which is capable of giving rise to infection. It is, therefore, necessary in such observations to ascertain whether there is any dead wood underground from which the tree may have become infected. Where attacked trees are situated within or adjacent to areas which have been previously infected it is

sometimes possible to form some idea as to the probable time-rate of death from the disease. Plants of one or two years of age appear to succumb to the disease usually within from four to eight months after they are attacked. Older plants may live on for a longer period after they are infected. From observations on old trees situated adjacent to areas which have been infected, I have estimated that a period of two years may have elapsed before death occurred, after infection had commenced.

The more important factors which have been elucidated above in connexion with the spread of the disease by the mycelium may be briefly summarised as follows:—

(1). The mycelium of the fungus appears to show no appreciable capacity for resting in the soil when its normal source of food supply has been removed; when the growing mycelium is unable to come into contact with living or dead roots or when the soil containing the mycelium is cleaned of roots and timber, the mycelium soon dies out.

(2). The disease can be spread by the growth of the mycelium from infected to healthy roots; the mycelium occurs on the roots of dead jungle trees which thus provide a source of infection in the planted area. The mycelium grows most rapidly where the material is dying or but recently dead, and the danger of infection is greatest where there is an abundance of such material in the land, *i.e.* immediately after the jungle has been felled and burnt.

(3). Damp conditions favour the growth of the mycelium.

(4). The mycelium occurs in greater quantity in the uppermost eighteen inches of the soil, but it can occur at greater depths and has been recorded at a distance of three and a half feet below the surface of the ground.

(5). The disease makes its appearance usually at the end of a year or eighteen months after the area has been planted. The fungus can, however, infect younger plants, and it has been found that infected plants have sometimes been transferred from the nursery to the field.

(6). The disease can be reproduced artificially by the growth of strands of mycelium from infected to healthy roots, which is concluded to be the usual mode of infection in the field.

(7). The time-rate of death of the plant from the disease is not easy to determine accurately; but such observations as have been made tend to show that plants of one or two years of age succumb to the disease usually

within four to eight months after they are attacked. Older plants may live on for a longer time. It is estimated for old trees that two years may elapse before they succumb to the disease.

B. SPREAD BY SPORES.

The fructification is, generally speaking, not commonly met with except on some occasions on lowlying land where damp conditions prevail. On higher and on more exposed ground it is usually somewhat difficult to find. It is seldom found on dead trees of *Hevea,* since these are usually removed before it has had time to develop, *i.e.* before the mycelium has been able to accumulate a growth above ground which is necessary for the development of the fructification. Where the dead trees are allowed to remain for some time the fructification may be produced. I have on two occasions recorded the fructification of the fungus on trees which were not yet dead. In one case it was present on a part of a lateral root which was above the surface of the ground, and in the other case it was present at the base of the root adjacent to the "collar" of the stem. In these cases the external conditions, dampness, shade &c., were favourable to the development of the fructification. The fructification occurs on fallen logs, on the stumps of dead jungle trees, and on the roots of dead jungle trees which become exposed in the making of drains. Photograph III shows the fructifications on a dead stump. Whenever the fructification makes its appearance it avoids the exposed parts of the dead wood; on logs it occurs on the undersides and on stumps it is most frequently met with in some hollow or on the protected side. On the edges of drains it is often seen to best advantage. In one instance I observed in swampy land clumps of the "brackets" along the edge of a large drain for a distance of about forty yards; in this case almost every stump whose laterals projected at the edge of the drain bore the fructifications.

From the fact that the fructifications are only abundant on damp lowlying ground and usually make their appearance in shady places it would appear that dampness and shade are the two predominating external factors in their development.

The fructification more frequently takes the form of a "bracket." The "brackets" may arise singly; but, if the fungus be allowed to grow unchecked, several brackets may develop together fusing with each other and producing a

Photograph 111

clump. The bracket varies from a few inches to as much as about 8 inches in width and from one-half to about one centimetre in thickness. The colours of the upper and under surface serve as a ready means of identification. The upper surface is zoned with alternating reddish brown and paler yellowish brown zones which run parallel with the margin of the "bracket;" it is also grooved with concentric grooves and has striæ which run at right angles to the grooves. The colour of the upper surface soon fades as the fructification dries, the reddish brown zones becoming more obvious as bands. In the fresh fruits, however, the zoning is clearly visible. The margin is of a bright yellow colour and is more obvious in younger fruits. The under surface is of a bright orange and is studded with minute holes which are scarcely visible to the naked eye. The photographs facing pages (20 and 22) show respectively the upper surface of a small collection of "brackets" and a clump of "brackets."

The fructification may take on another form in which it is spread over the wood, possessing an orange surface which is uppermost, bounded by a yellow margin, the upper surface of the "bracket" being absent. This form is known as resupinate and is not common. I have found it on some occasions on fallen logs on damp ground.

The fructification may be obtained by keeping infected roots in damp soil for a period of a few months. Its development is often assisted by covering lightly with straw, lalang† etc. It takes origin above the surface as a yellow knob which grows out horizontally into a bracket, the yellow margin being particularly obvious in the young stages.

The fructification when fresh may be easily broken, *i.e.* it is woody. If it be broken it is found to consist internally of two distinct layers. The upper layer is white and is composed of fibres which run for the most part parallel to the upper surface. The lower layer is of a bright orange colour and is composed of a large number of tubes which are arranged vertically and which open externally on the orange-coloured under surface.

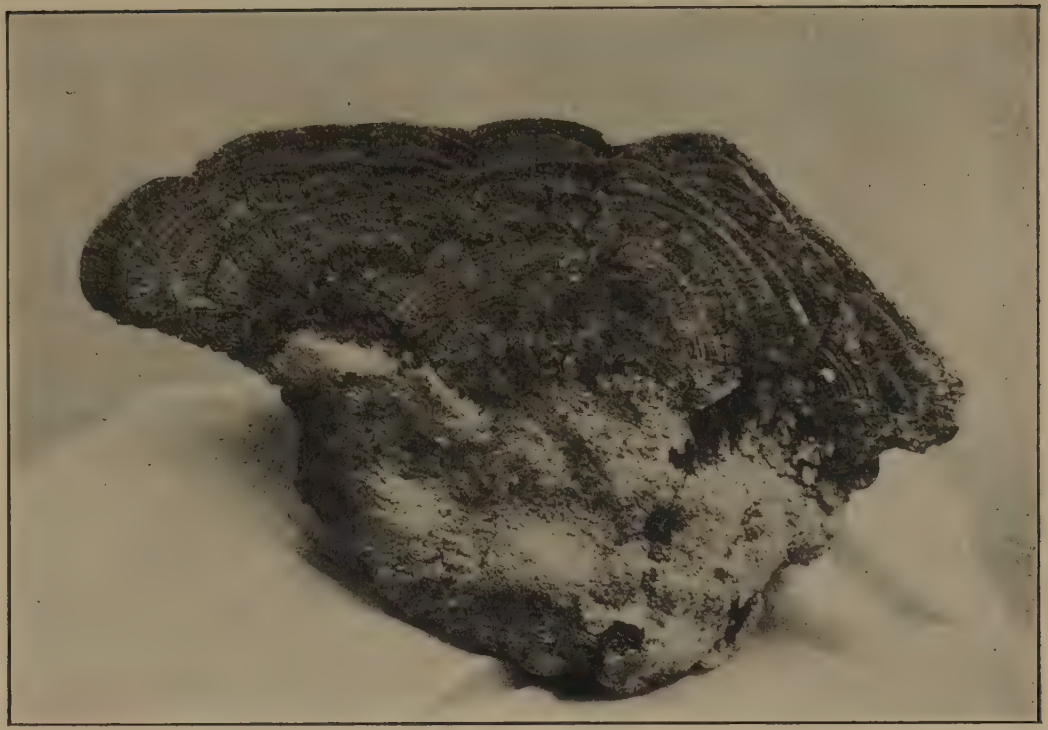
Within the tubes the spores take origin from a special layer, the *hymenium*, which lines the inner surface of each tube. The spores are ejected from the pores on the under surface of the "bracket." They are small, round bodies and

† *Imperata arundinacea*.

may accordingly be expected to be capable of being carried for some distance by the wind. The brackets are eaten by insects of various kinds which no doubt also serve to distribute the spores.

Of a series of attempts which have been made to reproduce the mycelium of the fungus by sowing the spores on dead wood in one case only was a growth of mycelium obtained, which lasted for a short time and then died out. The method which was adopted consisted in obtaining the spores in water by scraping the under surface and macerating lightly the spore-bearing parts of mature fructifications, transferring the liquid to dead roots which were half-buried in soil in boxes, and covering lightly with soil.

Artificial experiments on the reproduction of the fungus by spores may be expected to be difficult to carry out successfully, and negative results can scarcely be regarded as conclusive. The percentage of germination of the spores may be expected to be low and the exact conditions which are necessary for the production of the mycelium may be difficult to obtain. A satisfactory conception of the spread of the disease by spores can best be obtained by making a series of observations in planted areas. Young "stumps" have been found to develop the root disease a few months after they were planted; and although in some few cases the infection has been found to be due to the close proximity of infected jungle stumps, yet in the majority of cases there was no sign of the fungus on any of the adjacent jungle stumps. In the latter it has been possible in some instances to trace the infection back to the nursery from which the plants were taken; while in other instances no record of the nursery could be obtained. It would appear that all of the cases in which plants have died from the root disease soon after they were planted may be explained either by the close proximity of infected roots in the field or by the plants having been previously infected in the nursery. Apart from these, all of the cases which have been met with among young rubber, up to five or six years of age, have been found to be due to infection from the roots of a neighbouring dead stump. Sometimes, where no dead stumps were visible above the ground, the source of infection has been found to be a dead root which was buried below the surface. Among older plants, of seven years or more, situated on land from which the timber has for the most part disappeared, there have been many cases in which the disease has recently been observed; but



Photograph 4.

the infected trees have always been adjacent to trees which had previously died from the root disease, *i.e.* they were situated adjacent to infected areas. Such cases are due either to absence of employment of methods of sanitation or to incomplete isolation of the infected areas.

So far, then, as direct infection is concerned, I have never been able to record a case in which a tree may be said to have developed the root disease through the germination of the spores of the fungus on its roots. Petch records a case in which a twelve-year-old tree of *Hevea*, planted among tea which was twenty-five years old, died from the disease. He concludes that this was infected by spores, since all of the timber had long disappeared from the land. It is possible that trees may become infected by the germination of the spores on the exposed injured parts of lateral roots; but, cases of direct infection would appear to be rare.

In some cases, on lowlying land, jungle stumps which have been dead for six or seven years have been found to bear the mycelium and sometimes the fructifications of the fungus, although none of the living trees in the area have ever developed the root disease. It is highly probable that if these stumps had been infected for any considerable period of time some of the surrounding trees would have developed the disease, since the young roots of trees of six years of age form a fairly close network over the planted area. The areas containing these stumps were adjacent to other areas which had harboured the mycelium and fructifications of the fungus for several years, and it is probable that some of them, at any rate, represent instances of the spread of the fungus by means of spores.

While direct infection of the living plant by spores would appear to be comparatively rare, there are instances in which the fungus appears to have been propagated from one dead stump to another through the agency of the spores. Such stumps as become infected from this source would accordingly serve as sources of infection for the living trees.

The fructifications are only produced in small quantity, except in some instances on damp lowlying land; and although this is disadvantageous from the point of view of diagnosing the disease, yet it is advantageous in that if the fructifications were more abundant there would be a greater danger from the propagation of the fungus by the spores.

The disease may accordingly be said to be spread by the stumps which are primarily infected in the jungle, by the growth of the mycelium from one jungle stump to another, by the transference of the spores from one stump to another, and finally perhaps, in a few instances only, by the germination of the spores on the roots of the living plants. Of these the two former appear to be decidedly the more important sources of infection.

OTHER HOSTS.

In addition to the Para rubber the fungus has been recorded on Formosan camphor, robusta and Liberian coffee.

Several plants of Formosan camphor have from time to time developed the root disease in the experimental gardens at Kuala Lumpur; the plant is also readily susceptible to attacks from the brown root fungus, *Hymenochaete noxia*.

Robusta coffee, which was originally supposed to be immune to the root disease,* has been found to be attacked in the field, and I have also been able to infect the young plants artificially from bits of dead roots which bore the superficial strands of the fungus. It is interesting to note that this plant is also readily susceptible to the leaf spot caused by *Hemileia vastatrix*. The plants which are growing in the gardens at Kuala Lumpur have shown for the most part more spotted leaves than those of Liberian coffee with which they were growing side by side. Other observers have also found the plant to be susceptible to the leaf disease both in Ceylon and Java.

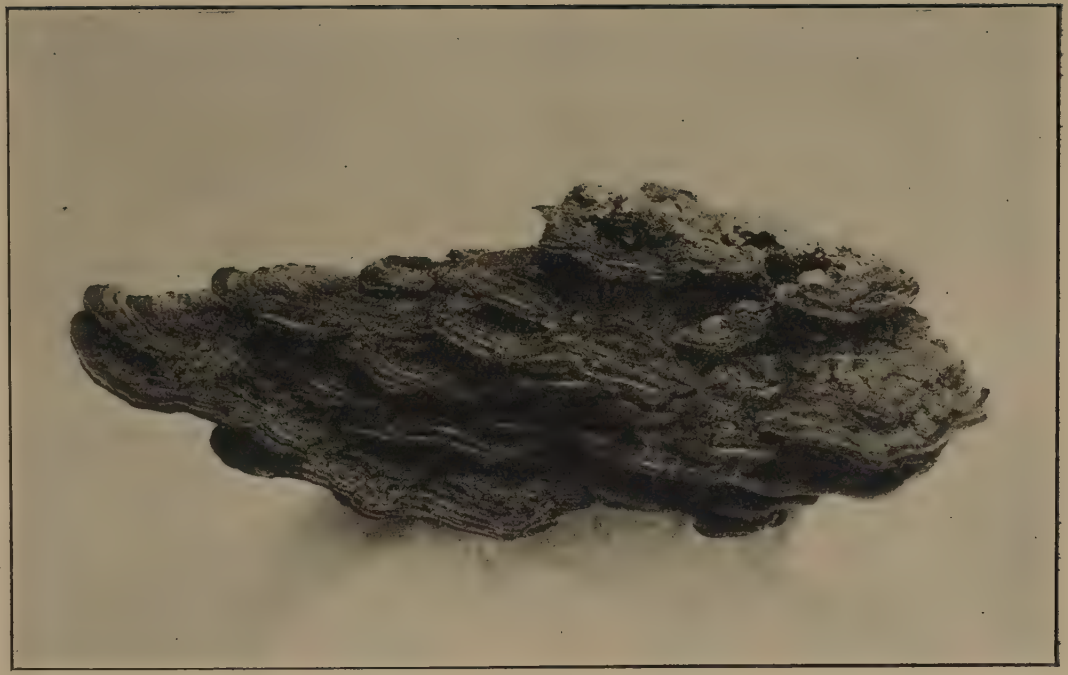
The stumps of Liberian coffee have in some cases proved a source of infection to *Hevea* which has been planted on old "coffee land."

Tapioca has been said to harbour the mycelium of the fungus. This requires special mention, if the records of the mycelium on the roots of tapioca are correct, since the tapioca plant possesses soft roots and one is liable to associate the mycelium of the fungus with woody roots.†

With regard to the hosts among jungle trees it was obviously of great importance to ascertain whether the fungus was limited to any small or definite number of hosts. Were it possible to associate the mycelium with only certain kinds of stumps in "clearings," a method of selective stumping would be applicable, by which the cultivator would be able to recognise those stumps which were likely

* Cramer, India Rubber Jounal, July 1910. p. 46.

† I have recently had an opportunity of observing the fungus on tapioca in large quantity.



Photograph 5

to harbour the mycelium of the fungus and would accordingly select them for removal. Petch considers that the fungus does not live on all kinds of stumps, but that it is limited to stumps of definite species. He has recorded the fungus on the jak tree (*Artocarpus integrifolia*) and on bombax (*Bombax malabaricum*); he further states that a large number of jak trees were felled on the experimental station at Gangaruwa during 1902-1904 and the stumps were subsequently covered with the fructifications, but that no root disease occurred among the tea, cacao or dadaps, although these were in many cases in contact with the decaying stumps. Gallagher recorded the fructification of the fungus on serdang (*Livingstonia cochin-chinesis*), and also stated that he found the disease spreading from meranti (*Shorea sp.*) and merabau (*Afzelia sp.*).

In certain parts of this country where the nibong (*Oncosperma filamentosa*) is abundant, as in the lowlying land near the coastal districts of Selangor and Perak, I have on very many occasions found the fructifications of the fungus on the stumps of the plant.

The kumpus, or kĕmpas, (*Koompassia malaccensis*), a gigantic tree with large buttresses, is well known to harbour the mycelium of the fungus. This plant possesses a hard wood and is difficult to fell; for this reason it is often left by jungle clearers. It is a formidable host by virtue of its large root system. Stumps of bamboos have been found to bear the fructifications of the fungus. Serdang, meranti and merabau have also been observed to harbour the mycelium. The above mentioned list includes about a dozen species belonging to widely separated families and comprising both hard and soft woods.

Some observations have been made from time to time in recent "clearings" consisting more especially of jungle swamps, in which the fungus is often abundant. One such area which I have had under observation for about twelve months deserves special mention; it consisted of about 25 acres of swampy land and was by far the worst infected area which I have seen. The area contained mixed stumps of many species, and the fructifications and mycelium of the fungus were found to occur indiscriminately on hard and soft woods, red and white woods. In some parts of the area on which the lateral roots were exposed by the making of drains almost all of the exposed roots developed the fructifications on the edges of the drains. The majority of the stumps on this area have borne the fructifications of

the fungus. In fact, so many different stumps were infected that the Estate Manager suggested that it would be much easier to attack the problem from the opposite point of view and to ascertain whether there were any stumps which were not infected. From these observations, coupled with the fact that the mycelium has been found on species belonging to widely separated families, it does not appear to be reasonable to suppose that a selective method of stumping would be practicable.

The fungus is essentially a wood destroyer, and in view of this it is possible that the mycelium may not grow readily on plants which possess soft roots.† Further, it may be said that the smaller the area which is covered by the root system the more liable is the plant to escape infection.

METHODS OF TREATMENT.

Isolation, sanitation, etc. of infected areas. As soon as the disease makes its appearance in the planted area by the death or blowing over of infected trees, the infected areas should be isolated by means of a trench. The uses of the trench are two-fold; in the first place it acts as a boundary between the infected area and the surrounding trees and thus limits that area from which the fungus must subsequently be eradicated, and secondly it severs communication between the trees without and within the infected area. Two considerations are of primary importance with respect to isolation, *viz.* that the trench must be sufficiently deep to sever the lateral roots of the trees within and without the infected area, and that the area which is enclosed by the trench must include the whole of the area in which the mycelium of the fungus occurs. In most cases a depth of two and a half feet is sufficient to isolate the infected area; but, if there is reason to believe that the lateral roots of any of the jungle trees occur to a greater depth than two and a half feet the trench must be made deeper in order to sever these laterals. In by far the majority of cases it is of little or no use to isolate a single dead tree by a trench, since the stump which is the cause of infection will usually be outside the isolated area. When a single tree dies from the root disease the trench should in most cases include not only the dead tree, but the eight trees adjacent to it. An examination of the lateral roots of the dead tree will frequently indicate the direction from which infection has arisen, since the lateral root which has been dead longest

† See footnote on p. 22.

may be assumed to have been first attacked; this examination will also frequently indicate the position of the infected stump, and will thus enable the cultivator to draw conclusions as to which of the adjacent trees are attacked by the disease and as to the size of the area in which the mycelium occurs. In the diagram facing page (26) a single tree A is supposed to have died and the position of the trench B.B. is shown, the remaining trees, still living, are indicated thus O. The same system for isolation holds good where two adjacent trees have died, the trench being made so as to include not only the dead tree, but the next tree adjacent to it. When the area has thus been isolated, it should be dug over and all dead wood to a depth of two and a half feet should be removed and burnt on the spot; it must not be thrown outside the trench. Various other methods have been employed for isolating by trenches, but the form of trench illustrated facing page (26) has been found the most serviceable.

The roots of the living trees within the trench will be exposed and it will thus be possible to ascertain whether any of these are infected. If only one or two laterals of any of these trees are infected they may be cut off to a point where they are healthy, and the diseased part should be burnt; but, if the tap root of any of the trees are diseased the whole tree should be removed and the roots and about one foot of the lower part of the trunk should be burnt. In some cases I have been able to save trees by cutting off lateral roots and that portion of the tap root which bore the strands of mycelium. The removal of diseased roots does not, however, always prove satisfactory, since it is necessarily difficult to determine what roots are infected. Some observers are in favour of cutting out the whole of a tree if it shows any signs of being attacked by the fungus; and this is certainly the safer plan to adopt. In any case excision of diseased roots should only be attempted where the work can be carefully supervised. It must be borne in mind that methods of treatment should be so directed as to eradicate the mycelium of the fungus and to prevent another attack from the root disease rather than to save the life of a single tree here and there.

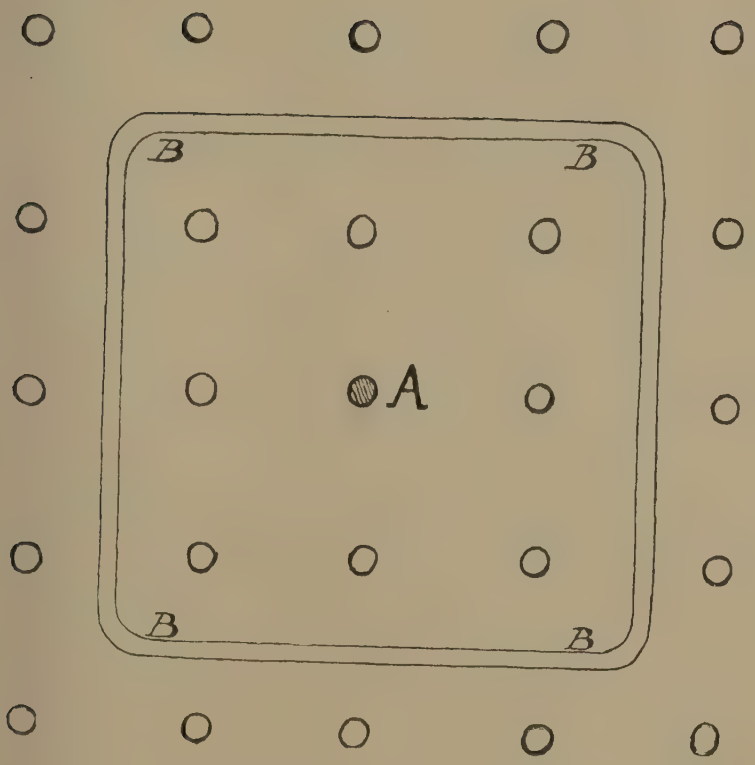
When the area has been dug over once it is advisable to dig over a second time after an interval of about a month and to turn in lime at the rate of 25 lb. to every square of 10 x 10 feet of the surface. The lime acts as a fungicide and also produces an alkaline medium which is

unfavourable to the growth of the mycelium. The photograph facing page (28) shows the work of isolating and digging over an infected area.

Supplying. When an infected area has been treated by isolation, by the removal of dead wood and by liming, it should, if possible, be supplied. In order that "supply" plants may be successful in their growth it is necessary that they should have a good access to the light and that the area should be free from the mycelium of the fungus. The fate of the "supply" will accordingly depend partly on the age of the surrounding trees, their rate of growth and their distance apart from each other. Where a single tree has been killed it is only possible to supply it when the neighbouring trees are quite young; but, when two or more trees are killed at each centre of infection, it is usually possible to replace some of them. Generally speaking supplying is done up to the sixth or seventh year.

It has been mentioned above that in order to ensure success in supplying the area must be free from the mycelium of the fungus. Accordingly it has been supposed that some time must lapse before the area is supplied, after it has been treated. In some cases it has been found that "supplies" which were put in at the end of a month have flourished, while those planted at the end of a year have died from the root disease. In several cases I have found that the "supplies" have died within a few months of their being planted and have ascertained that they have been put either on or in contact with a dead root. In connection with the spread of the disease it was shown that the mycelium of the fungus cannot live in the soil for any appreciable period of time if its normal source of food-supply be removed, *i.e.* if the soil be free from plant material, either living or dead; whereas it can live on and in the tissues of dead roots for a considerable period of time. The time of supplying, therefore, depends on whether the dead wood has been properly removed or not. It has been found that where the infected areas have been dug over a second time and limed, and the work has been carefully done, the "supplies" can be put in within a few weeks.

Preparation of Nursery Beds. The disease does not often occur in the nursery, since the beds are usually cleaned of timber before the seed is sown. But, there are some cases in which infected plants have been transplanted from the nursery and have died from the root disease within a few months from the time of planting. In one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instance I recorded the death of fifteen adjacent plants which had been transplanted from a nursery where the fungus was subsequently found to be present. Care should, therefore, be taken to remove all wood to a depth of two and a half feet before the seed is sown.

Drainage requires special mention in connexion with the treatment of the root disease, since damp conditions favour the growth of the mycelium. Where the fungus occurs on badly drained, lowlying land it effects a very rapid growth; and badly infected areas have shown considerable improvement under an efficient system of drainage.

The fructifications of the fungus serve as a means of locating an infected stump, and kanganies or mandors should be made to become acquainted with them so as to report on their occurrence. In this way infected areas may be located. Any stump which bears the fructification should be removed and burnt on the spot.

The complete removal of the timber from the land. The root fungus makes its appearance in recent "clearings" on the roots and stumps of the dead jungle trees, and from these the mycelium spreads to the living roots of the trees of *Hevea* with production of the root disease. The dead logs which are present on the surface of the ground sometimes harbour the mycelium, but the principal source of infection is from the timber which is present under the ground. It has been shown above that the mycelium does not retain its vitality in the soil for any appreciable period if the dead wood be removed and that the danger of infection is greatest when there is an abundance of dead and dying material on the land. From this it is clear that the removal of all of the timber from the land is a means of eradicating the mycelium of the fungus, and that if this method is to have its full effect it should be done at the outset, *i.e.* before planting is commenced. In order to exterminate the mycelium of the fungus altogether it would be necessary to remove not only the stumps and surface timber but also the lateral roots of the dead trees.

If the timber is got rid of before planting is commenced there will necessarily be a delay in planting, which on a large area may be considerable. After the area has been planted up the timber can usually be got rid of more cheaply, since a certain period of time has lapsed and decay has commenced. The destruction of stumps has, however, frequently resulted in considerable damage to the planted

trees by scorching. In some cases the trees are killed outright, while in others they may be rendered untappable for several years. Even under very careful supervision scorching is not always avoidable.

The cost of removing timber from the land varies according to the nature of the timber, whether light or heavy, the labour, the district and other factors. For Chinese working by contract, the form of labour which is usually employed for this work, prices are quoted ranging from $50.00 to $150.00 per acre for fresh timber. Generally speaking, it appears to be possible to extract the stumps and burn off the surface timber soon after felling for under $95.00 per acre. For older timber the prices range usually from $25.00 to $70.00 per acre.

The presence of timber on the land serves to prevent "wash" on hilly ground; but it increases the cost of weeding, tapping and collecting the latex and may render supervision difficult. These difficulties are reduced by piling the timber between the rows of the trees; and in the case of heavy timber this has proved very serviceable.

Before drawing any conclusion as to whether it is advisable to remove the timber from the land or not, it is necessary to consider the question of permanency of the root disease, *i.e.* how long will cases of the disease continue to recur if the timber is allowed to remain? On planted areas from which the timber has not been removed there is usually a recurrence of fresh cases of the disease until about the end of the fourth or fifth year of cultivation, providing that the infected areas are properly treated as soon as they have been located. This means that by the end of the fourth or fifth year all of the infected stumps have yielded up their cases of disease and the infected areas have been located, cleansed and supplied. In one instance, which deserves special mention, I found that up to the end of three and a half years after planting there had been a death rate of 16% of trees over an area of 350 acres. The removal of timber was limited to the infected areas only, which were thoroughly cleansed and supplied. After this period no fresh cases were recorded, and the trees are now nearly five years old. In addition to the cases of the root disease which are recorded in the first few years of cultivation and which appear to be due to stumps having been infected primarily, *i.e.* either in the original jungle or by the spread of the mycelium in the recent "clearings," it is possible that older stumps may become infected by means

DIGGING OVER AN INFECTED AREA.

of spores and thus give rise to the disease; but the danger of infection from this source appears to be very slight. The fact that cases of the root disease are recorded in this country among trees of six years of age or older is no indication that the root disease will continue to exist in the planted area for a number of years unless the timber is removed, since it is only within recent years that the root fungus has been identified and the disease treated. There are numerous instances in which the treatment was commenced when the trees were five years old, and in some cases it was not commenced until the seventh or eighth year of cultivation; this implies that the fungus was allowed to grow unchecked for several years.

Accordingly, there appears to be sufficient evidence to show that the disease can be successfully eradicated if careful attention is paid to the treatment of the infected areas or centres of infection, although the bulk of the timber be allowed to remain. The complete removal of timber from the land would appear in most cases to be extravagant. It is most important, however, if the timber be allowed to remain on the land, that the cases of disease should be properly treated as soon as they are located. There are some cases in which the land should be cleared of as much timber as possible. There have been some instances on the lowlying land in which the disease was not treated in the early years of cultivation, and consequently a number of older trees continue to develop the root disease; in such cases the infected areas are difficult to locate, and the land should be cleaned of timber and properly drained. Again in the opening up of swampy land, where the fungus is abundant and the conditions are favourable to its spread the land should be cleaned of timber and properly drained from the outset. Such cases which would appear to warrant the outlay of expenditure necessary for the complete removal of the timber are, however, exceptional.

Other methods of treatment which have been suggested from time to time, such as the planting of a crop which would be immune to the disease and would allow the timber to decay before the *Hevea* was planted, the planting of a crop which would yield a quick return and would permit of the stumps and timber being removed after it had been planted, the general application of a fungicide to the soil and its local application to the roots of infected plants have been discarded either because they are regarded as being unnecessary or are considered to be impracticable.

OTHER ROOT FUNGI.

Of the other root fungi which have been found to be parasitic on the Para rubber plant only one, *viz.* "the brown root disease," caused by *Hymenochaete noxia*, has occurred in the Federated Malay States. This fungus has been recorded in small quantity on estates here and there, a few trees only on each estate having been attacked. The growth of the mycelium is very slow and there is no spread through the soil. The fungus does not appear to be a source of serious danger in this country. An account of the disease has been given in the Agricultural Bulletin, S. S. and F. M. S., Vol. X, No. 4, 1911, p. 106.

The mycelium of a fungus which was said to be the cause of a root disease of *Hevea* in Malaya was reported in the Agricultural Bulletin, S. S. and F. M. S., Vol. I, 1901, p. 81, as that of *Helicobasidium mompa*, a parasite on the mulberry tree in Japan; there has been no further record of its occurrence in this country, and it is possible that the mycelium was that of *Hymenochaete noxia*.

Another fungus, *Irpex flavus*, a common saprophyte in this country, was reported as being parasitic on *Hevea* in the Agricultural Bulletin, S. S. and F. M. S., Vol. V, No. 3, 1906, p. 64. I have, however, never been able to record it as a parasite. The fungus has been supposed to cause damage to cultivated coffee in the East.

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The following Bulletins have been published by the Department of Agriculture.

1. Notes on *Termes Gestroi* and other species of *Termites* found on Rubber Estates in the Federated Malay States by H. C. Pratt, Government Entomologist.

2. Root Diseases of *Hevea braziliensis*, the Para Rubber Tree: by W. J. Gallagher, Government Mycologist.

3. Observations on *Termes Gestroi* as affecting the Para Rubber Tree, and methods to be employed against its Ravages: by H. C. Pratt, Government Entomologist.

4. A Lepidopterous Pest of Coconuts, *Brachartona catoxantha Hamps*, (Zygaenidae): by H. C. Pratt, Government Entomologist.

5. The Extermination of Rats in Rice-Fields: by W. J. Gallagher, Government Mycologist.

6. A Preliminary note on a Branch and Stem Disease of *Hevea Braziliensis*: by W. J. Gallagher, Government Mycologist.

7. Coffee Robusta: by W. J. Gallagher.

8. The Cultivation and Care of the Para Rubber Tree (in Malay).

9. Die-Back Fungus of Para Rubber and of Cacao: by Keith Bancroft, Assistant Mycologist.

10. A Lecture on the Para Rubber Tree: by W. J. Gallagher.

11. Coconut Cultivation: by L. C. Brown, Inspector of Coconut Plantations.

12. Padi Cultivation in Krian; by H. C. Pratt, Government Entomologist.

13. A Root Disease of Para Rubber, *Fomes Semitostus*; by Keith Bancroft, Mycologist.

14. The Die-back Disease of Para Rubber and a Note on the Leaf Diseases of Para Rubber: by Keith Bancroft, Assistant Mycologist.

15. Camphor; its Cultivation and Preparation in the Federated Malay States, by B. J. Eaton, Agricultural Chemist.